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THE EFFECT OF LEACHING ON DRIFT PEBBLES

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How different rocks endure the superficial agencies of leaching and solution may be seen from the composition of pebbles in bowlder clay where this has been subjected to the solvent action of meteoric waters.

Many years ago the writer took occasion to collect fifty-eight lots of 100 pebbles each, from bowlder clay in Louisa County, in Iowa. By collecting pebbles of one size, about one-half inch, and by taking all of this size to be found on a limited space of the clay surface, unconscious selection of different kinds of rock was avoided. Thirty-seven of these samples were taken from places where the drift was in its original condition, unchanged by subsequent weathering or decay. Twenty-one samples were taken from the upper part of the bowlder clay, where it had been more or less leached and weathered.

In this region the bowlder clay is overlain by loess. The leaching of the clay sometimes extends five feet under the loess, but more often less than this. From this upper part of the till, calcareous material may be partly or entirely absent, so that there is no reaction for carbonates when acid is applied to the clay. Pebbles of limestone, which were no doubt originally present, have wholly or partly disappeared, and only less readily soluble materials remain. The leaching is most complete in the uppermost part of the till, and from here to the unaltered material below, is a zone in which the leaching is incomplete in varying degree. Limestone pebbles in this zone are either etched on the surface, or else they have suffered partial internal solution and are porous and even crumbling and are often yellow or brown from residual or infiltrated ferruginous material.

Below is a table which gives the percentages of the most important rocks noted in the study of the pebble samples collected. In the first column are the averages of thirty-seven samples of 100 pebbles each, all from till which had not been perceptibly altered. In the second column are the averages of seven samples of 100 pebbles each, taken from somewhat leached till. The third column represents averages of seven similar samples from till somewhat more affected by leaching. The fourth column shows the average percentages for seven similar samples taken from till representing extreme conditions of leaching.

TABLE SHOWING CHANGES CAUSED BY LEACHING, IN PERCENTAGES OF DIFFERENT KINDS OF PEBBLES PRESENT IN BOWLDER CLAY

Kinds of Rocks	1	2	3	4
Flint, chert, jasper (and felsite)	11.2	27.2	45.1	59.0
Vein quartz	7.0	13.5	17.3	21.0
Sandstone and quartzite	4.7	8.0	7.0	8.0
Concretionary hematite	1.0	3.0	1.8	1.0
Granite and gneiss	7.7	11.8	7.7	5.1
Greenstone, schists (and shale)	5.5	7.9	3.7	1.9
Diabase and other volcanic rocks	10.5	15.5	8.6	2.6
Dolomitic limestone	20.10	5.3	2.4	0.2
Calcareous limestone	27.0	5.2	0.5	0.0
Decayed limestone and undetermined rocks	0.5	5.4	3.0	1.7

Under the action of the destructive agencies to which the pebbles of the drift have been exposed in this region, the ratios of the numbers of pebbles of different classes of rocks have undergone progressive changes. These changes indicate that the groups of samples represent successive stages of a general progress of solution. This progress involved a gradual removal of the most soluble rocks. The different kinds of materials are arranged in the table in the order of decreasing resistance to destruction. The end of the process in this case is the removal of practically all pebbles consisting of calcareous limestone. This results in a corresponding increase in the ratios of the numbers of the most resistant pebbles. This increase is greater or less according to the relative resistance of each class of rock.

Beginning with flint, we find that while these pebbles count only about eleven to a hundred in the till that still remains unchanged, they make, in the most thoroughly leached till, 59 per cent. In one of the seven samples of 100 pebbles of which 59 per cent is an average, there were 70 flint pebbles. In the group of flint were counted a few pebbles of jasper and of a black felsite. Some, which here is called flint, should perhaps have been called chert, which contains some calcareous material. This is present as a mixture throughout the mass of the chert, and in the leached condition of the chert it has been dissolved away, leaving a rock which is a porous silica that readily absorbs water.

Under "vein quartz" were classified the white quartz pebbles which are derived from quartz veins in crystalline rocks, and which themselves have a crystalline structure, although the external crystalline form is hardly ever developed and only very rarely preserved in the pebbles. This form of quartz is somewhat less resistant than flint. While the percentage of flint is more than five times greater in the most leached till than in the unleached, the percentage of vein quartz is only three times as high.

Sandstone and quartzite were classified together for the reason that in the most thoroughly leached till it is often impossible correctly to distinguish the two. In leached quartzite the bond uniting the grains is sometimes weakened and the rock has in effect again become a sandstone. This may lead to the false conclusion that sandstone resists weathering better than does quartzite. Sandstone is, of course, a rock of variable qualities of resistance and strength. The varieties of sandstone and quartzite represented in this drift together are a little less enduring than vein quartz. It appears that they are only about twice as numerous as the vein quartz pebbles in the most thoroughly leached till.

Angular pieces of hematite of variable hardness are present in a small quantity in this till. Sometimes they are in part carbonate of iron. They were originally fragments of clay-iron-stone concretions, which are now mostly changed to iron oxide. Observations on compact hematite pebbles on the plains indicate that these are almost as enduring as flint, but the hematite pebbles in this till suffer somewhat more rapid destruction than sandstone and quartzite and are only about as enduring as granite and gneiss.

At first, the destruction of hematite, granite, gneiss, greenstone, schists, shale, diabase, and other igneous rocks proceeds much more gradually than does the leaching-away of limestone. In a partially leached till, where some limestone pebbles are still left, the ratios of these rocks to the total are higher than in the unaltered till. In the classes named, gneiss, schists, shale, and volcanic rocks, other than dark diabase or diorite, form unimportant parts of the groups. Basic crystalline rocks evidently resist leaching and weathering less effectually than the acidic rocks.

Dolomitic limestone and calcareous limestone, which occur in about equal quantities in this drift, are both much more promptly removed than any of the other rocks. The ratio of such pebbles to the total is reduced to less than one fourth of its original value before the other rocks have been much affected. In the final stage the ratio of the dolomite pebbles to all others is 1:500, and the calcareous limestone has disappeared entirely. A limestone pebble is extremely rare in till, the body of which gives no reaction for carbonate of lime.

These observations show that under the conditions of weathering and leaching in the prevailing climate and drainage of this region, flint is one of the most enduring materials. It is the last thing to yield to solution and general weathering. It is relatively highly insoluble and tough. This explains why flint is a common and large ingredient in the gravel veneer found on the plains and plateaus of the West. It is always an important, and in places almost the only, ingredient in the oldest Pleistocene gravels of the South. The Uvalde formation in Texas consists of gravel consisting almost entirely of flint. About 70 per cent of the gravel taken in the Ohio at Cincinnati consists of flint and quartzite, brought largely from the residual surface material in the upper basin of this stream. Such gravels are also common in some parts of the Pennsylvanian in the central states, and these sediments are known to have been deposited during an era of extensive erosion and hence also general leaching of the land.